PLANTERS' ASSOCIATION OF CEYLON,

(KANDY.)

INTERIM REPORT

ON

COCOA DISEASE,

BY

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COLOMBO:
PRINTED AT THE "TIMES OF CEYLON" STEAM PRESS.

1898.

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In this report I propose to confine myself almost entirely to a statement of observed facts as far as they seem at present to lead to a knowledge of the Cocoa disease ; but many facts observed are unrecorded here, and may at a future time be of use when a final and fuller report on the investigation is submitted.

Leaving England at short notice I had no time to make myself acquainted with any literature which might bear directly on these diseases of cocoa if any such exists, and, therefore, on arriving here began *ab initio* in my researches into the cause of the deterioration and death of the diseased trees.

The Director of the Royal Botanic Gardens very kindly placed at my disposal the result of his observations on the disease, as well as all the information he had accumulated from planters and other sources, and the two most valuable circulars issued by him showed me the knowledge of the disease possessed by planters up to that time.

At the estate where I began my work I was fortunately able to see diseased trees of all ages, both of Forastero and Red Cocoa, and had every facility given me for experimenting on these and on healthy trees.

The fact that trees of all ages, from three or four years upwards, in the best and richest soil and in favourable aspects, were attacked, and that trees apparently in a most healthy condition became victims to this disease, pointed to its being the result of extraneous parasitic organism—either plant or animal—no animal injuries could be found *exclusively* on diseased trees, and therefore the supposition that it might be due to a fungus was a fair one, and I at once proceeded to learn if this was the case by discovering the fungus and endeavouring to induce it in a previously healthy tree.

The conditions favourable for the growth of fungi are moisture and heat; the latter of these is always sufficient in this country, but the former is more occasional. At the time of my arrival the North-East Monsoon was providing a time most advantageous to fungi, and I spent the first weeks in collecting and examining all the fungi I found upon the Cocoa tree. Here I may say that one of the difficulties in an investigation of this sort is the very large number

of fungi to be found in the cocoa like all other plants, which are either saprophytic, *i.e.*, living on dead trees or dead portions of a tree, or merely superficial, like the Lichens. Both these classes are of little interest in this investigation, as the former, though often occurring with the disease, are an after-effect, appearing when the damage is done; and the latter have, as a rule, no effect whatever on the health of the tree. But the difficulty lies in distinguishing between these and the parasitic fungus which is the real cause.

In order to discover the nature of a fungus and so learn its life history, it is necessary to observe its reproductive organs, just as in identifying flowering plants the flower must be found. Two methods can be followed in such a research, either to discover the fruit of the fungus in the field (and this is naturally a not very easy matter, owing to the small size of the reproductive organs of fungi), or to place some of the mycelium or roots of the fungus under conditions most favourable to their reproducing themselves, and keep them under close observation.

The difficulty in this latter method, especially in this country, is the large quantity of Bacteria, Torulae and other organisms which it is almost impossible to exclude from the cultures, and which destroy the fungus under observation.

In the case of the cocoa disease it was necessary in the first place to form some conclusion as to portions of the tree affected. The examination of the roots of badly diseased trees showed no sign of fungus, and other facts of importance in this connection are that trees, which are badly attacked, if cut down to within a few inches of the ground will produce from the remaining portion of the stem suckers which are perfectly healthy and produce round leaves and fruit; also that seedlings planted only a few inches from a badly diseased tree—so that their respective roots must be intermatted and touch at many points—grow vigorously without any signs of disease. These facts lead me to the opinion which, I think, I shall farther prove in this report that *the disease does not affect the roots.*

On coming to the examination of the stem and branches in diseased trees, patches on the bark can be observed with the naked eye, in some places claret coloured drops exude from the bark, and where these drops had presumably run over the surface, a characteristic rusty skin is produced, the patches were darker in colour and damp to the touch, and on cutting into them the tissues are found to be discoloured, their natural colour being changed to a neutral tint

or claret colour. On examining these portions microscopically the tissues are found to contain the mycelium (that is the vegetative portion) of a fungus, and also in large quantities bodies of a more or less spherical shape, the nature of which I at first thought to be fungal, through a certain resemblance to the rest spores found among certain groups of these plants—they, however, can be dissolved in Hydrochloric acid, and therefore I consider them to be cluster-crystals of Oxalate of Lime, the nature of which I am investigating and hope to elucidate. These bodies, however, have no connection with the fungus and are therefore of less importance.

The leaves are free from fungi and, in cases of a tree having died from disease, present all the appearances, on microscopic examination, that the leaves of a tree dying from want of moisture would have, thus showing that there is no disease in the leaf but that the death of the stem having cut off the supply of nutrition from the root, the leaves have died with the rest of the tree.

On coming to the fruit I noticed a very large number of dead and diseased pods of all sizes from an inch long, many of which were covered with saprophytic fungi and had died from causes which I hope at some future time to discuss; but others—and these the larger ones—were attacked by a disease which, from its occurrence on trees otherwise absolutely healthy and from its non-occurrence on cankered trees, I came to the conclusion has no connection with the canker, and the experiments which are afterwards described support this view.

The disease can easily be distinguished from the blackening of pods owing to drought or Helapeltis. It begins either at the point or at the stalk of the pod, almost never (about once in a hundred) in the middle, and creeps along the pod showing a well defined boundary of brown tissue encroaching on the yellow, red or green healthy tissues of the pod. If the pod is cut this will be found to discolour the whole of the tissue not to be merely a superficial injury as in some other cases of browning or blackening.

The damage that this pod disease has caused in Ceylon I cannot yet say, but where I have observed it, it has probably produced a loss of 15 to 20 per cent of the annual crop by attacking pods that were approaching maturity, and if the number of young pods killed and never picked were included in this estimate the figure would be much higher. This percentage is for the whole year during the wet season—favouring the growth of the fungus—more like 50 per cent of the crop was destroyed or rendered of much inferior value.

A microscopic examination of the discoloured tissue showed the quantities of mycelium, which was larger and of a different character from the mycelium in the stem, and a portion of it was placed under observation in a culture apparatus. After a few days the mycelium began to produce branches at the end of which egg-shaped bodies are borne. These egg-shaped bodies are seen to contain circular bodies, and are no doubt the sporangia or fruits of a fungus which belong to a group of plants, the greater number of which are parasites in the tissues of flowering plants and to which the well known Potato disease belongs.

A few days later I was able to confirm these observations by collecting from a pod in the field these same reproductive organs on the surface of the pod.

The fruit of this fungus can be easily recognised by the naked eye as a white mould occurring chiefly in the furrows of the pod. The rapidity with which the fungus completely permeates the comparatively soft tissue of the pod is shown by the experiments recorded later, and an important economic factor in dealing with this evil is that, after the pod has been well attacked by this fungus, no further nutrition reaches the seeds and they are found to undergo no increase in size. In the case of the younger pods where the seeds are still touching the husk, the fungus spreads into and destroys them, but if the pods have approached to that point of ripeness when the seeds are free from the sides of the pod, then the mycelium of the fungus does not cross the space and the seeds are untouched.

Having thus examined the whole tree and come to the conclusion that the stem was the seat of the disease causing the death of the trees, I began to watch carefully for any outward sign of a fungus which was causing the canker, but for some time without success. I also carried on many cultures of diseased bark in the hope that I might get the fructifications under these artificial conditions—all these cultures, however, fell a prey to the enemies I have mentioned before without having produced any reproductive organs.

However, on January 24th I found a white excrescence on the cankered portion of a Red Cocoa tree, and on microscopically examining it found it to consist of a mass of mycelium bearing oval shaped thin walled bodies which I placed under hourly examination in a drop culture. In the course of 12 to 15 hours these bodies began to push out tube like processes in diameter about $\frac{1}{4}$ the breadth of the oval bodies.

The processes in some cases grew more than ten times the length of the oval body in 18 hours; many of them sent out two tube like processes, in some cases three, and these frequently coalesced so that a string of two or more up to six or seven were all growing into one tube. These tubes grew and branched frequently, and after 50 hours produced some smaller branches slightly conical in shape, at the end of which were a number of spherical bodies, which, after a few hours, were seen to consist of bodies of the same shape as the original spores, and these in their term pushed out tube like processes in the same manner as previously described.

These facts leave no doubt that these oval bodies are *spores*. Spores are the portions of a fungus capable of producing a new individual, and they may for practical purposes be considered as the seeds of a fungus.

During the few weeks following the discovery of these white sporophores on the bark of the Cocoa, I found them on many trees in different parts of the Estate, and collected and examined a large amount of material. A fortnight later I found a sporophore which contained bodies of a different kind to the previous spores. These new bodies were about 6 times as big as the former spores and crescent shaped or in the form of a bent cylinder and usually 8 septate—*i. e.*, divided into 8 or less compartments. On placing these bodies under conditions favourable to their development they pushed out tubes from one or more of their compartments, and these tubes grew and branched until destroyed by bacteria and miscroscopic animals. In some cases in one sporophore I found both these spores occurring ; the smaller oval spores forming the mass of the outside of the sporophore and only a few of the larger spores occurring.

As is well known to students of mycology, the fact of these two kinds of spores does not necessarily point to there being two fungi, as many fungi produce different kinds of reproductive bodies, and my observations lead me to expect that in this case there will be a third kind of spore which will be found and will complete the reproductive bodies produced by this fungus. But as I wish this report to deal only with observed facts, I will not enter into any details with regard to this third form of spores.

With regard to the experiments which have been occupying my attention. In the first place I experimented with the pod disease and in the following manner: I took a number of pods in different stages of ripening and inoculated them, inserting

into a small space previously cut a piece of diseased tissue taken from another pod. I put the diseased portions in at varying depths and at different parts of the pod—thus, one was near the stalk and almost superficial, and another was much deeper and half way down the pod. In all the pods the disease was speedily induced, and in some of them in five days the whole pod became brown and the tissue full of the mycelium of the fungus. Those pods that were inoculated near the end of the pod took the disease soonest, and, as might be expected, where they were inoculated more deeply it began first. After some 8 days the spores of the fungus were produced in the furrows of one or two pods. From these facts we learn that the time taken for the disease to destroy the pod is comparatively short (as is the case with most fungi inhabiting soft tissue), I should estimate about 10 days from date of attack, and much less than that from the time the disease is just noticed on the pod.

The experiments with regard to the canker in the stem were more elaborate. I selected a number of trees 5-7 years old in different parts of the estate, and chiefly in new clearings of both Forastero and Red varieties, all of which to all appearances were entirely free from disease, and whose tissues showed no sign of mycelium when examined under microscope. These I proceeded to treat by inoculation. The method of inoculation adopted was to make a slanting cut so as to expose all the different tissues from the cortex to the old wood and to insert by means of a paint brush the spores, or in the case of those inoculated with diseased bark to insert a thin slice, and these cuts were then bound up firmly.

I used some 30 trees and treated them in the following way :—

1st. 13 trees inoculated with the smaller spores, which I have previously described.

2nd. 6 with the secondary septate spores.

3rd. 10 with diseased bark containing mycelium.

In each of these treatments both Forastero and Red Cocoa were used, and in one or two cases suckers were also treated.

Since these experiments were being carried on in an extremely dry season and the atmosphere was very different from the rainy times when the disease undoubtedly spreads, I wished to imitate as far as possible the conditions which are to be found in the wet seasons and so place these inoculated parts under the most favourable conditions for the

germination of the fungi. I therefore kept them damp by means of moist paddy straw, which was tied on to the tree, and re-wetted daily, after I had examined the case ; in cases where the sun had access and was likely to dry this up rapidly I placed shades over the part treated.

These were carefully watched for any sign of the disease, and, as will be supposed, those inoculated with the diseased bark containing the mycelium were the first to show any sign, and first of all a Red Cocoa produced the sporophores of the fungus after 9 days, and all the other Red Cocoa followed suit and acquired the disease with the exception of one tree in which the wet straw treatment had been intentionally omitted. In the case of the three Forastero trees treated with diseased bark, one has, up to the time of writing, taken the disease and the other two are in a suspicious condition.

In the eleven cases treated with the smaller spores, six were Forastero and seven Red Cocoa. Three of the Red have developed symptoms after more than 15 days, and one of the Forastero.

The cases treated with secondary spores (those described as crescent shaped and septate) have none of them at present shown any sign of the disease.

The external signs of the canker are being carefully observed and recorded, and permanent microscopic preparations made of its various stages, as well as many other observations and drawings which at present have no significance, but which, with the progress of the investigation, may be useful in throwing light on many questions of interest.

Usually the first external sign of disease is a moist spot on the tree with often a drop of claret or brown coloured liquid exuding from it. When this runs over the surface of the bark it gives it a rusted appearance—later the sporophores burst through the bark at different places, being at first white in colour and changing gradually to a red or brown—the size of these sporophores varies from that of a pin's head to almost the size of a pea, and the shape is as a rule round or oval. In the cases on older bark they are forced through the cracks already existing in the bark, and thus they appear more or less in vertical lines. The tissue is at first of a neutral tint, and later becomes brown and finally dark claret coloured. In most of the cases observed the fungus seems to spread more rapidly round the tree than vertically, but the rapidity of growth varies in the different trees and no opinion can be as yet formed as to this most important matter.

The three trees not kept moist by means of wet paddy straw have none of them acquired the disease, and this during the recent dry weather is as expected. In regard to the trees which have developed symptoms of the canker, those inoculated with tissue containing the mycelium would not usually be sooner affected than those treated with spores—just as transplanting is quicker than growing from seed. No doubt much valuable knowledge as to means of prevention or cure will be gained from these trees as well as that for which the experiments were instituted, the observation of the different stages of growth of the fungus.

With regard to the future work, the main question still to be solved by observation and experiment are the following :— The conditions of heat or dryness which will prove fatal to spores. The time—if any special time exists—for the formation of each kind of spore. The means by which the spores gain entrance into the tissues of the stem, whether they first germinate outside the bark or get in by a wound—and in this connection it must be remembered that the spores being of such a minute character need no appreciable wound. To give some idea of their size—in the case of the small spores first mentioned more than 50 million would be required to cover with one layer a square half inch, which is about the same superficial area as a ten cent piece,

Another extremely important question on which I am making many observations and experiments is the question of the effect of heat and dry atmosphere on the cankered spots of the tree. I have observed in many cases that the characteristic moist claret coloured tissue dries up, and on cutting has all the appearance of dead wood, In these cases the mycelium is not to be found in a microscopic examination, and if present at all must be in a dried up and probably entirely lifeless condition. The conditions which bring this about and whether the tree subsequently forms new and healthy tissue at the spot are problems which must be discovered. The question of the effect of cutting out portions of the canker how far in bad cases it is practicable, and what measures should be taken, if any, for protection of the wound is of great practical importance and will be experimented on at different estates where the conditions vary.

So far as these investigations have gone—and they are of course in an incomplete state—though certain facts have been established, yet it is too soon to talk of possible preventives or cures—and a cure in these cases of parasitic fungi in permanent parts of a plant is always a more difficult problem to deal with than a prevention.

Until a complete knowledge of the enemy you are dealing with has been gained, all experiments in these directions must be empiric and to a certain extent unsatisfactory, yet it may be well to state the facts already learnt and what precautions they teach us to take. In the case of the canker the malady is due to a specific disease caused by a fungus which inhabits the growing tissues of the stem, and in the pods such a disease caused by a different fungus also exists.

As I have previously observed, the conditions necessary for the growth of fungi are moisture and heat—the heat in Ceylon is always sufficient, but the moisture can be to a certain extent controlled. During the rainy seasons the atmosphere continues moist where the sun is not shining, but when the sun is up, unless the place is too densely shaded the atmosphere must speedily become too dry for the germination of spores. It is thus most important that a minimum of shade should be employed—the amount of shade necessary for the profitable cultivation of cacao—to prevent attacks of Helapeltis, to protect from wind, and other reasons are questions which experience in planting shows, and which I will not presume to advise, but from my point of view, as far as the canker is concerned, this shade should be reduced as far as possible.

It also follows from the observation already made that a great risk is run by allowing any bark on which the sporophores or spore bearing portions are present to remain on the trees, and all this should be destroyed by burning, which is the only absolutely effectual means of ensuring the destruction of fungi. This also applies in the case of the pod disease, which should be stamped out if care is taken to destroy the husk of every pod as soon as it is observed to be attacked.

Any report until the life history of the fungus has been entirely observed, and the rate of growth of its different stages determined is, to a certain extent, unsatisfactory, and therefore it is of great importance that those interested in the cacao disease should remember that this is only a portion of the result of an investigation carried on as far as is possible on scientific principles, and that hasty conclusions on data more or less incomplete are not likely to materially help in the eventual elucidation of the questions of prevention and cure.

J. B. Carruthers.

March 26th, 1898.

ADDITIONAL NOTE AS TO EXPERIMENTS.

On many Cocoa estates the superintendents reading this report may be inclined to themselves help on this investigation, and, therefore, a few remarks as to experimental work which they could do may be of use.

The most important point in carrying out such experiments is exactitude in recording what has been done, and after observation what the effects are at regular and frequent intervals. No doubt much useful information will be gained if the data are carefully recorded, and it is hardly necessary to specify the exact knowledge to be got by each experiment. I will therefore briefly state one or two examples of how to treat such cases.

1. To cut out carefully the whole of a cankered part taking care that no discoloured tissue remains behind and leave the wound so made to the drying influence of the air, and also, if possible, to take a stem which gets direct sunlight on it. (Neither of these experiments of course could be expected to succeed in thick shade).

2. To cut as in No. 1 and treat the wound with tar.

3. To cut as No. 1. and treat with Bordeaux mixture as recommended by Mr. Willis in his report, viz :—

Copper Sulphate (Blue stone) ...	6 lbs.
Quick Lime	4 lbs.
Water	45 gallons.

4. To scrape the cankered parts without entirely cutting them out and apply the mixture.

5. To cut out strips about one inch apart and about one inch in breadth in the cankered parts and treat as before.

In all the cases of using Copper sulphate as a fungicide, its liability to being washed off is a difficulty, and experiments with regard to modifying this are important. They may, however, be left to the ingenuity of the individual experimenter if it is always remembered that the basis of the application must be the blue stone. In France molasses have been used, and this mixture resists the action of the rain remarkably well, using only one tenth of the weight of molasses to that of Copper sulphate. Dextrine linseed oil and other

TABLE OF INOCULATION

No.	Kind of Tree.	Age.	What innoculated with.	How treate
1	Forastero	5-6 years	Small primary spores	Cut and damp s
2	Forastero	,, ,,	,, ,, ,,	,, ,,
3	Forastero	,, ,,	,, ,, ,,	,, ,,
4	Forastero	,, ,,	Diseased tissue	,, ,,
5	Forastero	,, ,,	,, ,,	,, ,,
6	Forastero	,, ,,	,, ,,	,, ,,
7	Red Cacao	,, ,,	Septate spores	,, ,,
8	Red Cacao	,, ,,	,, ,,	,, ,,
9	Red Cacao	,, ,,	,, ,,	,, ,,
10	Red Cacao	,, ,,	Diseased tissue	,, ,,
11	Red Cacao	,, ,,	Diseased tissue	,, ,,
12	Red Cacao	,, ,,	,, ,,	,, ,,
13	Forastero	,, ,,	Small primary spores	,, ,,
14	Red Cacao	,, ,,	,, ,, ,,	,, ,,
15	Forastero	,, ,,	,, ,, ,,	,, ,,
16	Red Cacao	Suckers.	,, ,, ,,	,, ,,
17	Red Cacao	,, ,,	,, ,, ,,	,, ,,
18	Red Cacao	,, ,,	,, ,, ,,	,, ,,
19	Forastero	5-6 years	,, ,, ,,	Scraped and dam
20	Forastero	,, ,,	Diseased tissue	Scraped and dam
21	Red Cacao	,, ,,	,, ,,	Cut and damp str
22	Red Cacao	,, ,,	,, ,,	,, ,, ,,
23	Red Cacao	,, ,,	,, ,,	Cut: no protectio
24	Red Cacao	,, ,,	Septate spores	Cut and damp str
25	Red Cacao	,, ,,	,, ,,	,, ,, ,,
26	Red Cacao	,, ,,	,, ,,	Cut and no protec
27	Red Cacao	,, ,,	Small primary spores	,, ,, ,,
28	Red Cacao	,, ,,	,, ,, ,,	Cut and damp str
29	Red Cacao	,, ,,	,, ,, ,,	,, ,, ,,
30	Red Cacao	,, ,,	Tertiary spores	,, ,, ,,
31	Red Cacao	,, ,,	Nothing	,, ,, ,,
32	Forastero	,, ,,	,,	,, ,, ,,

F = Fungus. ! = Suspic

* These trees were not experimented on till aft

substances have been used, but what is of course best is to use a cheap locally produced substance which can be readily obtained.

If these or any of these suggested experiments are carried out I shall be obliged if those superintending them will communicate with me, so that I may take advantage of the information gained and also, if possible, inspect the trees myself.

J. B. C.